

AQA GCSE Biology Notes: Homeostasis and Response (Topic 5)

These notes cover Topic 5, Homeostasis and Response, for AQA GCSE Biology (8461) and the Biology content of AQA Combined Science: Trilogy (8464). They cover control systems and homeostasis, the nervous system and reflex arc with the required practical on reaction time, the brain and eye, thermoregulation, the endocrine system and blood glucose control, the kidneys and water/nitrogen balance, hormones in reproduction, contraception, hormones used in infertility treatment, negative feedback in adrenaline and thyroxine, and plant hormones. Sections marked "Biology only" are not required for Combined Science: Trilogy, though the underlying idea of homeostasis and negative feedback is common to both courses.

1. Homeostasis: why the body needs control systems

Definition: Homeostasis is the regulation of the internal conditions of a cell or organism to maintain optimum conditions for function, in response to internal and external changes.

Cells only work efficiently within a narrow range of conditions, so the body regulates body temperature, blood glucose, water/ion levels and blood carbon dioxide. Control may be nervous or hormonal. Every control system has:

- **Receptors** – detect a stimulus (a change in the environment).
- **Coordination centres** – e.g. the brain, spinal cord and pancreas; process information and organise a response.
- **Effectors** – muscles (contract) or glands (secrete hormones) that carry out the response.

Most systems use **negative feedback**: a rise above normal triggers a response that lowers the level; a fall below normal triggers a response that raises it, keeping levels close to a set point.

AQA's three named examples of homeostatic control are core body temperature (around 37°C), blood glucose concentration, and the water and ion content of the blood (each covered in detail below). Breathing rate and depth also increase to help control blood carbon dioxide levels, but this response is covered under gas exchange and the response to exercise rather than examined as part of this homeostasis topic. Some responses involve only the nervous system, some involve only hormones, and some (such as blood glucose control during exercise) involve both working together.

2. The human nervous system

The nervous system lets the body detect and react to changes. Receptors convert stimuli into electrical impulses, carried by neurones to the central nervous system (CNS: brain and spinal cord), which coordinates a response sent to effectors.

Sense organ	Stimulus detected
Eyes	Light



Ears	Sound; also balance and head position
Nose	Chemicals (smell)
Tongue	Chemicals (taste)
Skin	Touch, pressure, temperature, pain

Pathway: stimulus → receptor → coordinator (CNS) → effector → response. Neurones meet at **synapses**; the impulse cannot cross directly, so a neurotransmitter diffuses across the gap and triggers a new impulse in the next neurone.

Feature	Nervous system	Hormonal system
Signal	Electrical impulse	Chemical, in the blood
Speed	Very fast	Slower
Duration	Short-lived	Longer-lasting
Area affected	Precise, localised	Often widespread

3. Reflex actions and the reflex arc

Definition: A reflex action is a rapid, automatic response to a stimulus that does not involve conscious thought, helping to protect the body.

Reflexes are fast because the pathway is short and bypasses conscious brain processing:

stimulus → receptor → sensory neurone → relay neurone (spinal cord) → motor neurone → effector → response

- **Sensory neurone** – receptor to CNS.
- **Relay neurone** – within the CNS; links sensory to motor neurone.
- **Motor neurone** – CNS to effector.

Example: touching a hot object. Skin receptors detect heat/pain; a sensory neurone carries the impulse to the spinal cord; a relay neurone passes it to a motor neurone; the motor neurone makes an arm muscle (effector) contract, pulling the hand away before the brain registers pain.

4. Required practical: investigating human reaction time

Method (ruler-drop test):

1. Hold a ruler vertically; the subject's thumb and forefinger start level with the zero mark, not touching it.
2. Release the ruler without warning.
3. The subject catches it as quickly as possible.
4. Read the distance fallen (or read time directly from a reaction-timer ruler).
5. Repeat several times for the same person, discard anomalies, and calculate a mean.

6. Repeat with the independent variable changed (e.g. with/without a distraction).

Variables: independent – the factor tested (e.g. distraction present/absent); dependent – reaction time (distance or time); control – same person, ruler, starting position and conditions each repeat.

Worked example: distance to time. A free-falling object obeys $s = 0.5 \times g \times t^2$, so $t = \sqrt{2 \times s \div g}$, with $g \approx 9.8 \text{ m/s}^2$.

Ruler falls $s = 0.18 \text{ m}$. $t = \sqrt{2 \times 0.18 \div 9.8} = \sqrt{0.0367} \approx 0.19 \text{ s}$. A shorter distance means a faster reaction.

5. The brain (Biology only)

Not required for Combined Science: Trilogy.

Region	Main function
Cerebral cortex	Conscious thought, memory, language, intelligence
Cerebellum	Coordination of movement and balance
Medulla oblongata	Unconscious activities: heart rate, breathing rate

Studying and treating the brain is difficult: the skull is hard to access without risking infection/damage, the brain is not fully understood, and many drugs cannot cross the blood-brain barrier. Methods used: MRI scanning; studying patients with brain damage. (Other techniques, such as electrically stimulating regions of the brain during surgery, also help map brain function, but only MRI scanning and studying brain-damaged patients are required by the specification.)

6. The eye (Biology only)

Not required for Combined Science: Trilogy.

Structure	Function
Cornea	Transparent; refracts light entering the eye
Iris	Controls pupil diameter, so light entering
Pupil	Hole through which light passes
Lens	Fine-focuses light onto the retina by changing shape
Ciliary muscles / suspensory ligaments	Change lens shape during accommodation
Retina	Contains light receptors (rods and cones)
Optic nerve	Carries impulses from retina to brain
Sclera	Tough outer layer; protects the eyeball

Definition: accommodation is the change in shape of the lens to focus on near or distant objects.

Near object: ciliary muscles contract → suspensory ligaments loosen → lens becomes fatter/more curved →

refracts light more strongly.

Distant object: ciliary muscles relax → suspensory ligaments pulled taut → lens becomes thinner → refracts light less strongly.

Defect	Cause	Effect	Correction
Myopia (short-sightedness)	Eyeball too long, or lens too curved	Image of distant objects focuses in front of the retina; blurred	Concave (diverging) spectacle or contact lens; or laser/lens-replacement surgery
Hyperopia (long-sightedness)	Eyeball too short, or lens under-refracts	Image of near objects focuses behind the retina; blurred	Convex (converging) spectacle or contact lens; or laser/lens-replacement surgery

7. Control of body temperature (thermoregulation)

Definition: Thermoregulation is the maintenance of a constant core body temperature around the optimum for enzyme action.

Core temperature is maintained at about 37°C, controlled by the thermoregulatory centre in the brain, which senses blood temperature and receives input from skin temperature receptors.

Situation	Blood vessels	Sweat glands	Effect
Too hot	Vasodilation: skin capillaries widen, more blood near the surface	More sweat produced; evaporation transfers heat away	More heat lost by radiation and evaporation; temperature falls
Too cold	Vasoconstriction: skin capillaries narrow, less blood near the surface	Little/no sweat; hair-erector muscles raise hairs to trap insulating air	Less heat lost; shivering increases respiration, releasing heat; temperature rises

8. The endocrine system

Definition: The endocrine system is a collection of glands that secrete hormones directly into the blood; hormones are chemical messengers carried in the blood plasma to target organs.

Gland	Hormone(s)	Main effect
Pituitary gland (base of brain)	FSH, LH, ADH, TSH, others	"Master gland": acts directly and stimulates other glands
Thyroid gland	Thyroxine	Regulates metabolic rate; role in growth/development
Adrenal glands	Adrenaline	Prepares body for "fight or flight"
Pancreas	Insulin, glucagon	Regulate blood glucose concentration

Ovaries	Oestrogen, progesterone	Menstrual cycle; female secondary characteristics
Testes	Testosterone	Sperm production; male secondary characteristics

9. Control of blood glucose concentration

The pancreas monitors blood glucose. After a carbohydrate meal, glucose is absorbed into the blood and blood glucose concentration rises.

Too high → pancreas secretes **insulin** → glucose moves from blood into cells (liver, muscle); liver converts glucose to glycogen for storage → blood glucose falls.

Too low → pancreas secretes **glucagon** → liver converts glycogen to glucose, released into the blood → blood glucose rises.

Insulin and glucagon have opposite effects, together forming a negative feedback loop that keeps blood glucose within a narrow range. People with diabetes often monitor their own blood glucose concentration using a finger-prick blood test or a continuous glucose monitor, so that treatment can be adjusted.

Feature	Type 1 diabetes	Type 2 diabetes
Cause	Pancreas produces little or no insulin	Cells no longer respond properly to insulin (resistance); often insufficient insulin too
Onset	Usually childhood	Usually later life; linked to obesity
Treatment	Insulin injections; carbohydrate-controlled diet; monitoring	Controlled diet; exercise; sometimes medication

Worked example: BMI. BMI = mass (kg) ÷ [height (m)]². Mass 88 kg, height 1.60 m.

Height² = 1.60 × 1.60 = 2.56 m². BMI = 88 ÷ 2.56 = 34.4 (3 s.f.). Healthy range ≈ 18.5 ≤ BMI ≤ 24.9, so BMI 34.4 is obese (≥30), raising Type 2 diabetes risk.

BMI is not the only measure used to assess obesity-related risk: waist:hip ratio (waist circumference ÷ hip circumference) is also used, with a higher ratio indicating greater risk. BMI can be misleading for very muscular individuals, since muscle is denser than fat and adds mass without adding fat-related risk.

10. The kidneys: water and nitrogen balance (Biology only)

Not required for Combined Science: Trilogy.

The kidneys remove urea from the blood and regulate ion and water levels (osmoregulation). Excess amino acids are broken down in the liver (deamination); the amino group forms toxic ammonia, immediately converted to less toxic urea for excretion.

- Filtration:** blood enters at high pressure; small molecules (glucose, water, ions, urea) are filtered into the kidney tubules. Large molecules (proteins, blood cells) stay in the blood.
- Selective reabsorption:** all the glucose, and the ions/water the body needs, are

reabsorbed into the blood. Urea and the rest leave as urine, stored in the bladder.

Water is lost via urine, sweat and exhaled air, and gained from food, drink and respiration.

ADH. Dehydrated (blood too concentrated) → more ADH released from pituitary → tubules more permeable → more water reabsorbed → small volume, concentrated urine.

Overhydrated (blood too dilute) → less ADH → tubules less permeable → less water reabsorbed → large volume, dilute urine.

Treatment	How it works	Key points
Dialysis	Blood passes a partially permeable membrane against dialysis fluid with normal glucose/ion levels but no urea; urea diffuses out down its gradient	Repeated several hours, several times a week; manages but does not cure failure
Kidney transplant	A matched donor kidney is implanted and takes over function	Needs close tissue matching; lifelong immunosuppressants; removes need for dialysis

11. Hormones in human reproduction

At puberty the pituitary triggers release of sex hormones (oestrogen in females, testosterone in males), producing secondary sexual characteristics. The menstrual cycle (~28 days) is controlled by four hormones.

Hormone	Source	Main effect
FSH	Pituitary	Matures an egg in the ovary; stimulates oestrogen release
Oestrogen	Ovaries	Thickens uterus lining; triggers LH surge; inhibits FSH
LH	Pituitary	Surge triggers ovulation (~day 14)
Progesterone	Ovary	Maintains uterus lining; inhibits FSH and LH; falling level causes menstruation

12. Contraception

Contraception is the deliberate prevention of pregnancy, using hormonal methods, barrier methods, or surgery.

Method	Type	How it works
Combined pill	Hormonal	Inhibits FSH, so no eggs mature
Progesterone-only pill	Hormonal	Thickens cervical mucus, blocking sperm
Injection/implant/patch	Hormonal	Slow-release progesterone (or oestrogen+progesterone); weeks to years
Intrauterine device (IUD)	Hormonal or non-hormonal	Releases progesterone, or (copper) prevents sperm survival/implantation

Condom	Barrier	Physical barrier; also reduces STI spread
Diaphragm/cap + spermicide	Barrier	Covers cervix; spermicide kills/disables sperm
Natural (rhythm) method	Non-hormonal	Avoids intercourse around estimated ovulation
Sterilisation	Surgical	Vasectomy or tubal occlusion; usually permanent

13. Using hormones to treat infertility: IVF (Biology only)

Not required for Combined Science: Trilogy.

Women with low FSH may not mature eggs naturally; FSH and LH given as fertility drugs stimulate egg maturation and release, and are also the basis of IVF.

1. Mother given FSH and LH to mature several eggs at once.
2. Eggs collected from the ovaries.
3. Fertilised with sperm in a laboratory dish.
4. Fertilised eggs develop into embryos.
5. One or two embryos inserted into the uterus.

Benefits: allows couples who could not otherwise conceive to have a genetically related baby. **Risks/ issues:** success rate not high and falls with age; physically/emotionally stressful; multiple embryos raise the chance of multiple pregnancy and associated health risks; ethical concerns over unused embryos; cost.

14. Negative feedback control of adrenaline and thyroxine (Biology only)

Not required for Combined Science: Trilogy.

Thyroxine (thyroid gland) controls basal metabolic rate and growth/development; controlled by negative feedback:

Thyroxine too low → pituitary releases more TSH → thyroid releases more thyroxine → level rises, reducing further TSH release.

Thyroxine too high → pituitary releases less TSH → thyroid releases less thyroxine → level falls.

Adrenaline (adrenal glands) is released in stressful/frightening situations, triggered by nerve impulses from the brain rather than by its own blood level. It increases heart rate, increases blood flow (oxygen/ glucose) to brain and muscles, and raises blood glucose by stimulating glycogen breakdown in the liver — a fast "fight or flight" response, rather than a classic level-controlled feedback loop like thyroxine. For example, a sudden fright increases heart rate within seconds, well before any change in blood hormone concentration could be detected and fed back on, which is why this response is better described as a rapid nervous-hormonal reflex than a negative feedback loop.

15. Plant hormones (Biology only)

Not required for Combined Science: Trilogy.

Definition: A tropism is the growth of a plant in response to a directional stimulus, such as light (phototropism) or gravity (gravitropism).

Auxin, made in shoot and root tips, controls cell elongation. In shoots, more auxin increases elongation; in roots, more auxin inhibits elongation — the opposite effect.

Response	Shoots	Roots
Phototropism	Positive: grow towards light. In one-sided light, auxin builds up on the shaded side, which elongates more, bending the shoot towards light	Little/no response in most GCSE examples
Gravitropism	Negative: grow upward, away from gravity. Auxin builds up on the lower side of a horizontal shoot, increasing elongation there, bending it upward	Positive: grow downward, with gravity. Auxin builds up on the lower side of a horizontal root, but inhibits elongation there, so the root bends downward

Gibberellins end seed dormancy and trigger germination; also involved in stem elongation and flowering.

Commercial uses:

- Auxins as selective weedkillers: disrupt growth of broad-leaved weeds without harming narrow-leaved crops/grasses.
- Auxins as rooting powder, to make cuttings grow roots for propagation.
- Auxins in tissue culture (micropropagation), to grow new plantlets from tissue samples.
- Gibberellins to end seed dormancy for reliable, simultaneous germination.
- Gibberellins to promote flowering and increase fruit size (including seedless fruit).
- Ethene, another plant hormone, is used to control fruit ripening: fruit is picked unripe for transport, then ripened using ethene before sale.

Key terms

Term	Definition
Homeostasis	Regulation of internal conditions of a cell/organism to maintain optimum conditions for function, in response to internal/external changes
Receptor	Cell/organ that detects a stimulus
Coordination centre	Part of the body (e.g. brain, spinal cord, pancreas) that processes information and organises a response
Effector	Muscle or gland that brings about a response
Negative feedback	Mechanism where a change away from normal triggers a response that returns the level to normal

Stimulus	A detectable change in the internal or external environment
Central nervous system (CNS)	Brain and spinal cord; coordinates responses
Neurone	Nerve cell that carries electrical impulses
Sensory neurone	Carries impulses from a receptor to the CNS
Relay neurone	Neurone within the CNS linking sensory to motor neurones
Motor neurone	Carries impulses from the CNS to an effector
Synapse	Junction between neurones; crossed by diffusion of a neurotransmitter
Reflex action	Rapid, automatic response to a stimulus not involving conscious thought
Reflex arc	Pathway of a reflex: receptor, sensory neurone, relay neurone, motor neurone, effector
Cerebral cortex	Brain region for conscious thought, memory, language, intelligence
Cerebellum	Brain region controlling coordination and balance
Medulla oblongata	Brain region controlling unconscious activities (heart rate, breathing)
MRI scanning	Imaging technique showing brain structure/activity without surgery
Cornea	Transparent front of the eye; refracts light entering
Iris	Controls pupil diameter and light entry
Pupil	Opening through which light enters the eye
Lens	Flexible structure that focuses light onto the retina
Retina	Light-sensitive layer containing rods and cones
Optic nerve	Carries impulses from the retina to the brain
Accommodation	Change in lens shape to focus on near or distant objects
Ciliary muscles	Contract/relax to alter suspensory ligament tension and lens shape
Suspensory ligaments	Hold the lens and adjust its shape with the ciliary muscles
Myopia	Short-sightedness; distant objects blurred; corrected with a concave lens
Hyperopia	Long-sightedness; near objects blurred; corrected with a convex lens
Thermoregulation	Maintenance of a constant core body temperature
Thermoregulatory centre	Brain region monitoring and controlling body temperature
Vasodilation	Widening of skin blood vessels, increasing heat loss
Vasoconstriction	Narrowing of skin blood vessels, reducing heat loss
Shivering	Involuntary muscle contraction increasing respiration to release heat
Endocrine system	Glands that secrete hormones directly into the blood
Hormone	Chemical messenger carried in the blood to a target organ

Pituitary gland	"Master gland" at the base of the brain; secretes hormones directly and stimulates other glands
Thyroid gland	Secretes thyroxine; regulates metabolic rate
Thyroxine	Hormone regulating metabolic rate and growth/development; controlled by negative feedback via TSH
TSH	Pituitary hormone that stimulates thyroxine release from the thyroid
Adrenal gland	Secretes adrenaline in response to stress/fear
Adrenaline	Hormone preparing the body for "fight or flight"
Pancreas	Monitors and controls blood glucose via insulin and glucagon
Insulin	Lowers blood glucose by promoting uptake into cells and glycogen storage
Glucagon	Raises blood glucose by converting glycogen to glucose in the liver
Glycogen	Storage carbohydrate made from excess glucose
Type 1 diabetes	Little/no insulin produced; treated with insulin injections
Type 2 diabetes	Cells stop responding properly to insulin; linked to obesity; treated by diet/exercise/medication
Body Mass Index (BMI)	$\text{Mass (kg)} \div [\text{height (m)}]^2$; used to assess obesity-related risk
Kidney	Organ filtering blood, removing urea, regulating water/ion balance
Deamination	Breakdown of excess amino acids in the liver, producing ammonia then urea
Urea	Less toxic waste made from ammonia; removed by the kidneys
Filtration (kidney)	Small molecules filtered from blood into tubules under pressure
Selective reabsorption	Useful substances reabsorbed from tubules back into the blood
Osmoregulation	Control of water and ion levels in the body
ADH	Pituitary hormone increasing water reabsorption by kidney tubules
Dialysis	Filtering blood through an external machine against a dialysis fluid
Kidney transplant	Surgical replacement of a failed kidney with a donor kidney
Menstrual cycle	~28-day cycle of ovary/uterus changes controlled by FSH, LH, oestrogen, progesterone
FSH	Matures an egg in the ovary; stimulates oestrogen release
LH	Surge triggers release of a mature egg (ovulation)
Oestrogen	Thickens the uterus lining; triggers the LH surge
Progesterone	Maintains the uterus lining after ovulation
Ovulation	Release of a mature egg from the ovary
Contraception	Deliberate prevention of pregnancy
Barrier method	Physically prevents sperm reaching an egg
Spermicide	Chemical that kills or disables sperm

Sterilisation	Surgical procedure permanently preventing fertilisation
Infertility	Inability to conceive a child naturally
IVF	Eggs fertilised with sperm in a laboratory, then embryos placed in the uterus
Tropism	Plant growth response to a directional stimulus
Phototropism	Growth response to light
Gravitropism	Growth response to gravity
Auxin	Plant hormone controlling cell elongation and tropisms
Gibberellin	Plant hormone ending seed dormancy; involved in stem growth/flowering
Ethene	Plant hormone used to control fruit ripening
Puberty	Stage of development when reproductive hormones trigger sexual maturity
Secondary sexual characteristics	Physical features that develop at puberty under hormonal control
Basal metabolic rate	The rate at which the body uses energy at rest
Concentration gradient	Difference in concentration between two regions, down which particles diffuse
Partially permeable membrane	A membrane that allows some substances through but not others
Fight-or-flight response	Rapid physiological changes, triggered by adrenaline, preparing the body for action
Seed dormancy	A period during which a seed does not germinate even if conditions seem suitable
Germination	The beginning of growth of a seed into a new plant
Selective weedkiller	A herbicide that kills certain plants (e.g. broad-leaved weeds) without harming others
Micropropagation	Growing many identical new plants from small samples of tissue using plant hormones

Quick check

1. Name the three main parts of an automatic control system. [3]
2. State the normal core human body temperature. [1]
3. Give the order of structures in a spinal reflex arc, from stimulus to response. [5]
4. Describe how the body responds when it becomes too hot, referring to skin blood vessels and sweating. [4]
5. Describe what happens to the lens, ciliary muscles and suspensory ligaments when the eye focuses on a near object. (Biology only) [3]
6. Explain why myopia causes distant objects to appear blurred, and state its correction. (Biology only) [3]
7. Explain, using glucagon, how the body responds when blood glucose falls too low. [4]

8. Compare Type 1 and Type 2 diabetes in cause and treatment. [4]
9. Calculate the BMI of a person of mass 70 kg and height 1.75 m, and state if it is in the healthy range ($18.5 \leq \text{BMI} \leq 24.9$). [3]
10. Explain how ADH helps control blood water content when a person is dehydrated. (Biology only) [4]
11. Explain, using auxin distribution, why a horizontal shoot bends upward while a horizontal root bends downward. (Biology only) [5]
12. Evaluate dialysis compared with a kidney transplant as treatments for kidney failure. (Biology only) [6]

Answers

1. Receptors; coordination centres; effectors.
2. 37°C .
3. Receptor → sensory neurone → relay neurone → motor neurone → effector.
4. Skin blood vessels dilate (vasodilation), so more blood flows near the surface and more heat is lost by radiation; more sweat is produced, which evaporates and transfers heat away, cooling the body.
5. Ciliary muscles contract; suspensory ligaments loosen; the lens becomes fatter/more curved, refracting light more strongly onto the retina.
6. The eyeball is too long or the lens too curved, so light is refracted too strongly and focuses in front of the retina instead of on it; corrected with a concave (diverging) lens, which spreads light out before it enters the eye.
7. Low blood glucose is detected by the pancreas, which secretes glucagon; glucagon makes the liver convert glycogen into glucose, released into the blood; this raises blood glucose back towards normal (negative feedback).
8. Type 1: little/no insulin produced; treated with insulin injections and a controlled diet. Type 2: cells stop responding properly to insulin, often linked to obesity; treated mainly with diet, exercise and sometimes medication, not usually insulin injections.
9. $\text{Height}^2 = 1.75 \times 1.75 = 3.0625 \text{ m}^2$; $\text{BMI} = 70 \div 3.0625 = 22.9$ (3 s.f.); within the healthy range (18.5–24.9).
10. Dehydration makes the blood more concentrated; more ADH is released from the pituitary; kidney tubules become more permeable to water, so more water is reabsorbed into the blood; a smaller volume of more concentrated urine is produced, conserving water.
11. Auxin builds up on the lower side of both a horizontal shoot and root. In the shoot, more auxin increases cell elongation, so the lower side grows faster, bending the shoot upward. In the root, more auxin inhibits cell elongation, so the lower side grows slower, bending the root downward.
12. Dialysis needs no donor/surgery and can start quickly, but must be repeated for hours several times a week for life, restricts diet/lifestyle, and does not cure the failure. A transplant can restore near-normal function and end regular dialysis, but needs a well-matched donor (possible long wait), major surgery, and lifelong immunosuppressants, which raise infection risk. The best choice depends on donor availability, health and patient

preference.